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LSD-induced effects in elephants: Comparisons with musth behavior

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Musth is a condition observed in male Asiatic elephants and is characterized by aggression and temporal gland secretions. A classic and controversial 1962 study attempted to induce a musth syndrome in an elephant via treatment with LSD. Two elephants in the present study survived dosages of LSD (.003-.10 mg/kg) and exhibited changes in the frequency and/or duration of several behaviors as scored according to a quantitative observational system. LSD increased aggression and inappropriate behaviors such as ataxia. Results are discussed in terms of musth and drug-induced perceptual-motor dysfunction.

Musth is a condition commonly observed in male Asiatic elephants and is characterized by aggressiveness and discharging of the temporal glands. Studies on captive domesticated Asiatic elephants (*Elephas maximus*) have demonstrated an initial stage wherein the temporal gland (a modified apocrine sweat gland) becomes enlarged and the animal displays increased irritability and decreased responsiveness to verbal commands. The second stage consists of temporal gland secretions (through a duct opening between the eye and ear), overt aggression, dribbling of urine, and elevated plasma testosterone levels (Jainudeen, Katongole, & Short, 1972; Jainudeen, McKay, & Eisenberg, 1972). The phenomenon clearly is related to chemical communication used in territorial marking as well as in sexual activity. In this sense, musth appears to be comparable to rutting behavior in other ungulates (Eisenberg, McKay, & Jainudeen, 1971) and may have adaptive significance for animals in the wild (Scheurmann & Jainudeen, 1972). Whereas musth has been observed only in Asiatic elephants, and only rarely in females (Bor, 1928), both male and female African elephants (*Loxodonta africana*) exhibit temporal gland secretions concomitant with aggression. Indeed, when African elephants are disturbed or stressed, the glands show copious secretions of oleic acid and volatile oils, which may function both as alarm signals and scents for individual recognition (Adams, Garcia, & Foote, 1978; Buss, Rasmussen, & Smuts, 1976; Cmelik & Ley, 1978; Jainudeen, McKay, & Eisenberg, 1972).

The behavior accompanying musth and temporal gland secretions may last from 2 weeks to 4 months and has been described as madness, insanity, and even violent psychosis. Carrington (1959) described such mad elephants as displaying either violent paroxysms of excitement or morose depressions. Among captive and work elephants, this violence may take the form of destructive rampages and the killing of human handlers and riders (Williams, 1954). According to folklore, elephants in the wild will attempt to place twigs in the glands of the young in order to prevent the "dazed or furious manners" of musth (Sanderson, 1962). But in captive-elephant situations, these elephants are often confined or destroyed (Lewis & Fish, 1978).

West, Pierce, and Thomas (1962) attempted to induce experimentally a behavioral syndrome resembling musth by administering the hallucinogen lysergic acid diethylamide (LSD) to a male Asiatic elephant. Following intramuscular injection of LSD (.10 mg/kg, or 297 mg/2,954-3,182 kg, b.w.), their elephant (Tusko) displayed trumpeting and restlessness, followed rapidly by ataxia, collapse, and seizure. Treatment with promazine (2,800 mg) and pentobarbital was followed by death at 100 min post LSD. The results failed to provide clear evidence of musth-like behavior, and the study has been the subject of controversy and criticism regarding issues of miscalculation of dosage (Harwood, 1963; Hoffer & Osmond, 1967) and toxicity of LSD independent of the other drugs (Witt, 1975). Because the original study has continued to receive attention and criticism (e.g., Jentzsch, 1983), the following study was conducted to correct procedural problems and reexamine the relationship between LSD and musth behavior in the elephant. Specifically, the study was designed to incorporate an observational behavioral profile sensitive to drug effects in elephants (Siegel & Brodie, 1984) as well as more careful testing of LSD dosages independent of additional drugs.

METHOD

Subjects

Two Asiatic elephants (one male, one female), born and

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reared in North America and with no history of musth, were used as subjects. The female was a subadult weighing approximately 1,500 kg, and the male was a young adult weighing approximately 2,000 kg. Both were housed in a barn and were maintained on a diet of alfalfa, grain, fruit, and water.

Apparatus

Observations of the elephants were made in the barn and in a small adjacent sandy yard. The elephants were usually chained to the barn, but occasionally were permitted access to the yard for brief periods in order to assess additional behaviors. Behaviors were coded in digital format with a Model DAK-8VC Datamyte portable recorder (Electro-General Corporation, Hopkins, MN). This instrument resembled a touch-tone telephone, and the observer entered behavioral codes via a 12-button keyboard. Depression of keys produced characteristic electrical signals that were automatically recorded onto a magnetic tape cartridge. A Teletype printout of raw data was later made from the tape for analysis of frequencies and durations of behaviors.

Behavioral Scoring Categories

The classification of behaviors was chosen after review of the literature (Benedict, 1936; Carrington, 1959; Laws & Parker, 1968; McKay, 1973; Sikes, 1971) and preliminary observations of subjects. Behaviors were chosen on the basis of their probable sensitivity to LSD. Because elephants were tested singly, no social behaviors were included here. The behaviors were recorded in terms of frequency, duration, and sequence. The final categories of behavior are defined as: *Aggression*–when elephant faces target with head raised and ears extended forward or laterally; sometimes accompanied by vocalizations and pushing. *Bathing*–rolling in dirt, mud, or water; throwing dirt, mud, dust, hay, or water onto body. *Down*–lying on side. *Drinking*–drawing in fluid with trunk and subsequent release into mouth. *Ear flapping*–extension of ears outward from the resting position snug against the head, and back again. Ear flaps occur in bouts on a variable-interval schedule and are not continuous. *Exploration*–tactile or olfactory exploration with trunk. *Feeding*–ingestion of food but not pica. *Head shaking*–lateral jerking and swinging of head, usually coupled with ear extensions and vocalizations. *Inappropriate*–any unusual behavior not often seen in normal elephants. *Rock/sway*–shifting of weight from side to side or smooth rhythmic swinging of head and trunk from side to side. *Vocalization*–growls, squeaks, snorts, trumpets, or other basic sounds.

Pilot Studies on LSD Dosages

The female elephant was used in pilot studies to determine procedures and dosages for LSD administration. Initially, the elephant was water deprived for 12 h, and then the LSD was administered orally in 18 liters of water. At least 1 week separated test doses. There was no apparent reaction to total doses of .025 or .100 mg. A dose of .300 mg, suggested by Harwood (1963), also failed to elicit observable responses. Doses of 1.0 mg administered orally or via intramuscular injection produced only mild restlessness and increased rocking and swaying. Disturbed vocalizations and some aggression following the injection procedure (via dart gun) prompted the use of oral administrations in subsequent sessions. Dosages of .003 mg/kg, calculated as the minimum effective behavioral dose derived from the theoretical LD-50 for elephants (cf. Hoffer & Osmond, 1967, p. 95), and .10 mg/kg (from West et al., 1962) were eventually chosen as the low and high dosages.

Procedure

Prior to LSD sessions, each elephant was observed for a total of 25 h, during which time baseline observations were recorded. One observer, located near the elephant, recorded the frequency and duration of behavioral postures. Observations were made for 2 h each day over a 2-month period during the summer.

During a given LSD session, the designated elephant was water deprived for 12 h and then given free access to a small calibrated bucket containing the LSD in 18 liters of water, followed by free access to water alone. This usually resulted in full intake of the LSD solution within 5 min. However, an important caveat is that the total dose may not have been ingested because some of the liquid was sprayed or dribbled from the trunk or mouth. Nonetheless, most of the LSD solution appeared to be swallowed. Five hours of Datamyte observations of the treated elephant were then recorded. Approximately 60 min of observations were conducted in the sandy yard.

RESULTS

Table 1 shows frequency or percentage of time each elephant engaged in selected behaviors during baseline and LSD sessions. Baseline scores were means calculated by combining the 25 h of preliminary observations. LSD scores were means calculated by combining all observations during the 5-h sessions. Frequency measures are expressed as mean rates per 10 min. Percentage-of-time measures are expressed as mean percentage of total observation time.

During baseline observations, both elephants spent most of the time rocking and swaying while chained in the barn. Exploration consisted mostly of trunk investigations of the observer, handler, or sandy yard. Ear flapping, a form of thermoregulation, remained relatively constant, as did vocalizations, which primarily comprised growls, which are short-distance contact calls to other elephants. As is clear from Table 1, the frequencies of other behaviors were extremely low.

Treatment with the low dosage of LSD produced dramatic changes in behavior within 10-20 min. The female showed a small increase in rock/sway time and slightly increased ear flapping and exploration. Perhaps the most interesting change was the increased inappropriate behavior marked by leaning with closed eyes and slightly ataxic gait. Vocalizations decreased but changed to short squeaks or chirping, which may indicate pleasure or conflict. The male showed similar, albeit more intense, behaviors, as well as head shaking and several aggressive displays.

The high dosage of LSD produced an initial aggressive display by the female, marked by trumpets and snorts, vocalizations that indicate extreme arousal. This was followed by increasing ataxia, with spread forelegs and hindlegs, and eventually by the animal's falling onto its side. It remained down for approximately 60 min and exhibited shallow respirations and some tremors, but when nudged by handlers, arose slowly and eventually regained an upright posture. Activity remained quiescent for the remainder of the session. The high dosage also produced an aggressive display in the male elephant, which repeatedly trumpeted and snorted while charging the observer. This was quickly followed by leaning with closed eyes and ataxia. Periodically, this inappropriate behavior was interrupted by aggressive displays or dust bathing. During all LSD sessions, both elephants refused feeding and most drinking. However, during the high-dosage session, the male bathed with the hay but did not eat it.

Table 1
Behavioral Scores for Each Elephant in Baseline and LSD Sessions

	Elephant and Session					
	Female			Male		
Behavior	Baseline	.003 mg/kg LSD	.10 mg/kg LSD	Baseline	.003 mg/kg LSD	.10 mg/kg LSD
Aggression	0	0	.08	0	.04	.35
Bathing	.10	.04	0	.07	.06	.55
Down*	0	0	38.60	0	0	0
Ear Flapping	2.27	2.44	1.20	2.33	2.91	2.00
Exploration	5.32	6.11	2.34	6.21	8.40	4.55
Feeding*	23.71	0	0	28.55	0	0
Head Shaking	0	0	0	0	.28	.07
Inappropriate*	0	.14	4.62	0	.77	1.65
Rock/Sway*	68.91	73.64	24.38	75.08	98.00	83.05
Vocalization	.25	.15	.10	.38	.55	1.00

**Down, Feeding, Inappropriate, and Rock/Sway scores represent mean percentage of total observation time. All other scores represent mean rates per 10 min of observation time.*

Within 24 h following LSD treatments, both elephants returned to normal baseline behaviors, including feeding and drinking. Examination of the temporal glands revealed no evidence of discharging.

DISCUSSION

The most apparent aspects of these findings is that two elephants survived low and high dosages of LSD that produced dramatic changes in behavior. Low dosages produced marked difficulty with motor behaviors, as demonstrated by increases in rocking and swaying and inappropriate behaviors. High dosages exaggerated these inappropriate postures, particularly the ataxic stance with spread legs. This stance is termed "the sawhorse posture" and is characteristic of animals treated with hallucinogens, including the elephant Tusko. The head shaking observed in the male elephant during both LSD sessions is also characteristic of ungulates and other mammals treated with hallucinogens. Both the sawhorse posture and head shaking have been described as evidence for disturbances in perceptual-motor systems, if not for hallucinations per se (Siegel & Jarvik, 1975).

West et al. (1962) observed 5 min of such behavior in Tusko before he collapsed; they termed the syndrome "pseudo-musth." In the experiment reported here, the male elephant exhibited musth-like behavior only briefly. This syndrome consisted of aggressive displays followed by overt aggression and sudden mood changes (e.g., stationary postures with closed eyes). The female displayed some aggression during the high-dose session, but the accompanying vocalizations suggested that this was more alarm and panic to the sudden onset of perceptual-motor symptoms than it was a threat. Nonetheless, both animals appeared somewhat unresponsive to verbal commands by the handler and, at times, had to be forced into the yard or back into the barn for observations. Yet these behaviors are more typical of elephants stunned and darted by immobilizing agents such as etorphine hydrochloride (M99) than of elephants in musth (Eltringham, 1982).

Taken together, these results suggest that elephants can tolerate high dosages of LSD but that the resultant behavior provides an unsatisfactory model for the natural aggression and behavioral disorders associated with musth or temporal gland secretions. Although the death of Tusko cannot be fully explained by this study, it appears that the absolute dose of LSD given to Tusko, who weighed almost twice what the elephants here weighed, may have been a major factor in exceeding some threshold for toxic effects, especially when injected rapidly. Such threshold effects are well known with respect to human reactions for hallucinogens such as mescaline. In addition, Tusko's heavy fall (followed by labored breathing, laryngeal spasm, and strangulation) and subsequent treatment with promazine and pentobarbital may have contributed greatly to the toxicity.

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